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PRIMITIVE EQUATION MODEL PROGRESS REPORT

NOVEMBER 1970 RESULTS

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PRIMITIVE EQUATION MODEL PERFORMANCE

NOVEMBER 1970

1. General

A program is available now to determine the monthly-mean error patterns at sea level and 500 MB for the 24-hour and 48 hour forecasts. In addition, comparative RMSE scores are produced for each forecast (out to 72 hours).

Table 1 contains the results for the month of November 1970. Note that points south of 20° North are omitted because they tend to mask the actual performance in the latitudes where significant changes are taking place. In general, the PE Model did exceptionally well, when compared to either the SLP or persistence. Although the SLP was often worse then persistence by 36-48 hours during November, it is noteworthy that every PE forecast contained skill through 72 hours. Figure 1 graphically illustrates the comparative results.

2. Mean Error Study

Figures 3 and 4 represent the mean error patterns in the month of November for the 24-hour and 48-hour PE sea-level pressure forecasts, respectively.

To interpret these results, some of the pressure distributions/ evolutions should be described. During this period, Asia and North America were dominated by cold highs. The Asian high was especially strong, with central values above 1050 millibars on occasions. Over the United States, the highs were progressive, with occasional interruptions by progressive lows crossing the northern tier of states. The N. Pacific was a very active cyclonic region. The N. Atlantic was also active, but less so than in the Pacific.

Referring once again to Figures 3 and 4, it is noted that the main systematic errors were diagnosed to be:

a. the overdevelopment of lows in the principal cyclone track across the northern Pacific.

COMMENT: There is no corresponding negative bias in the northern Atlantic, suggesting that with but a few additional upper-air soundings the initialization problem is minimized. Work is in progress to improve the surface stress terms; specifically to make the drag coefficient a function of the wind speed. Moreover, we plan to specify the initial divergent wind component within a matter of weeks.

b. the overdevelopment of continental highs, especially over Asia.

COMMENT: The model does not contain terms representing the heat storage of the land surfaces. This is important in the autumn when the relative warm surface modifies the lower part of the southward-moving cold highs significantly. Additionally, the model does not contain the initial specification of the divergent wind component. Further, both the analysis and prediction models contain insufficient vertical resolution to pose the temperature structure properly. Low-level inversions are not present. Consequently, it is difficult to model the sensible heat exchange with sufficient realism. In connection with the latter, note the tendency to move the Asian high eastward across China to Japan.

c. under-movement of pressure systems.

COMMENT: This model, like all other numerical models, has a tendency to under-translate small-scale pressure systems. This is the classical truncation error that is related to 200 nautical mile mesh length and the approximations which are implicit in the finite-difference operators. The smaller the horizontal scale of the system, the more difficult the problem becomes. In contrast, we have observed that the large-scale (SL) disturbance predictions contain considerable skill through 72 hours.

3. Interim Measures

Until notified that particular modifications have been implemented, it seems advisable for users to make local compensatory corrections based on the following information:

a. As a first approximation, most migratory continental systems and oceanic lows are under-translated by about 15 percent of the forecast displacement.

b. Cold lows over oceans are usually too deep by 3 to 5 millibars in 24 hours and 5 to 8 millibars in 48 hours, with little further bias beyond 48 hours.

c. Cold, continental highs are too strong by about 2 to 5 millibars in 24 hours and 4 to 8 millibars in 48 hours, depending on such factors as

   (1) Surface-air temperature difference (bigger bias for larger differences).

   (2) Horizontal scale of system (bigger bias for smaller scales).

   (3) Rate at which the high is changing latitude (bigger bias for faster meridional motion).

4. <u>Summary of 500 MB Prognoses</u>

Table 2 and Figure 2 summarize the comparative verification results for the PE and BARO 500 MB prognoses for November. Since the number of observations at 500 MB is only one-eighth of the number in a typical surface pressure analysis, the scores contain more uncertainty. (The best guess as to the RMSE of the initial and verification analyses is about 20 meters.)

The BARO 12-hour progs were slightly better than the 12-hour PE progs, but the PE becomes and remains better than the BARO by 18-24 hours. It should be noted that the 500 MB analyses are still biased in favor of the BARO since the 12-hour BARO progs are used to first guess the analyses. Yet, by 72 hours, the PE has about twice the skill of the BARO when compared to persistence.

5. Mean Errors in PE 500 MB Progs

Since the PE Model forecast surface pressure changes are obtained as an algebraic sum of the predicted flux divergences for the five layers in the model (from the continuity equation), the mean error patterns at sea level are highly correlated to the mean errors at 500 MBs. But, a proper error diagnosis for tropospheric height/temperature forecasts is much more complex than at sea level. For example, we integrate on sigma surfaces (which tend to be quasi-parallel to the underlying terrain at low elevations, but become quasi-horizontal with increasing height). The model knows the heights/temperatures on these surfaces only. At output time, interpolation/extrapolation procedures are used to get values on pressure surfaces. We assume that the temperatures/heights are linear-in-log P between sigma surfaces. Thus, it is possible to have an outstanding prog on sigma coordinates and generate errors from the foregoing procedures/assumptions.

Intensive work is currently in progress to alleviate these difficulties. The solution, of course, is to have increased vertical resolution in both the analysis and prediction models.

COMMENT. Question: What is the proper use of height progs? Until recently, the heights were used for

a. computing geostrophic winds

b. qualitative interpretation to determine the evolutions of pressure systems

c. computing the implied corresponding surface pressure changes (BARO-SLP Model).

The PE Model, on the other hand, completely eliminates all three of the traditional uses of height progs. Independent winds which are in proper balance with the mass fields are available from the model. These winds are weaker in troughs and stronger in ridges than geostrophic winds. Overplots of these winds on height fields show that cross-contour flow is present in about the regions where acceleration/deceleration should be occurring. Finally, the PE surface progs represent our best guess as to the evolutions of pressure systems. This relieves the field specialist of most of the prediction decisions. He can now concentrate on such things as interpretation and judgment, critical evaluation, prog modification and feedback.

Figures 5 and 6 contain the 500 MB Mean Error Patterns for the 24-hour and 49-hour PE progs, respectively.

TABLE 1

VERIFICATION RESULTS OF NOVEMBER 1970 SURFACE PROGNOSES
(in Millibars)

FORECAST PERIOD (HOURS)	FORECAST CHANGE		ACTUAL CHANGE	FORECAST ERROR	
	SLP	PE		SLP	PE
12	2.487	3.155	4.294	3.472	2.965
24	4.381	4.613	6.919	5.790	4.492
36	6.101	8.323	8.333	7.630	5.926
48	7.514	9.153	9.320	9.215	7.081
60	8.523	10.057	9.970	10.501	8.501
72	9.377	10.456	10.198	11.297	8.957

NOTE. RMSE scores are computed for all grid points north of 20° North. The inclusion of tropical points would make these figures considerably smaller.

TABLE 2

VERIFICATION RESULTS OF NOVEMBER 1970 500 MB PROGNOSES
(in Meters)

FORECAST PERIOD (HOURS)	FORECAST CHANGE		ACTUAL CHANGE	FORECAST ERROR	
	BARO	PE		BARO	PE
12	32.665	38.418	43.477	28.934	31.832
24	56.422	59.749	68.909	44.628	41.729
36	68.262	75.143	85.966	59.547	57.016
48	77.741	85.990	98.491	74.407	67.114
60	85.428	96.037	105.581	87.997	77.124
72	91.481	101.634	109.313	98.066	86.903

NOTE. RMSE scores are computed for all grid points north of 20° North. The inclusion of tropical points would make these figures considerably smaller.

TABLE 3

VERIFICATION RESULTS OF NOVEMBER 1970 36-HOUR PE MODEL

SURFACE PROGNOSES

AREA	RMSE (millibars)
NORTHERN HEMISPHERE (EQUATOR TO POLE)	4.2
LAND POINTS	5.1
SEA POINTS	3.5
LAND REGIONS:	
Americas	5.8
Asia	5.7
Near East	2.1
Europe	5.0
OCEAN REGIONS:	
Atlantic	3.6
Pacific	3.5
Indian	1.6
Mediterranean	3.3

SEA LEVEL PRESSURE PROGNOSES VERIFICATION RESULTS

NOVEMBER 1970

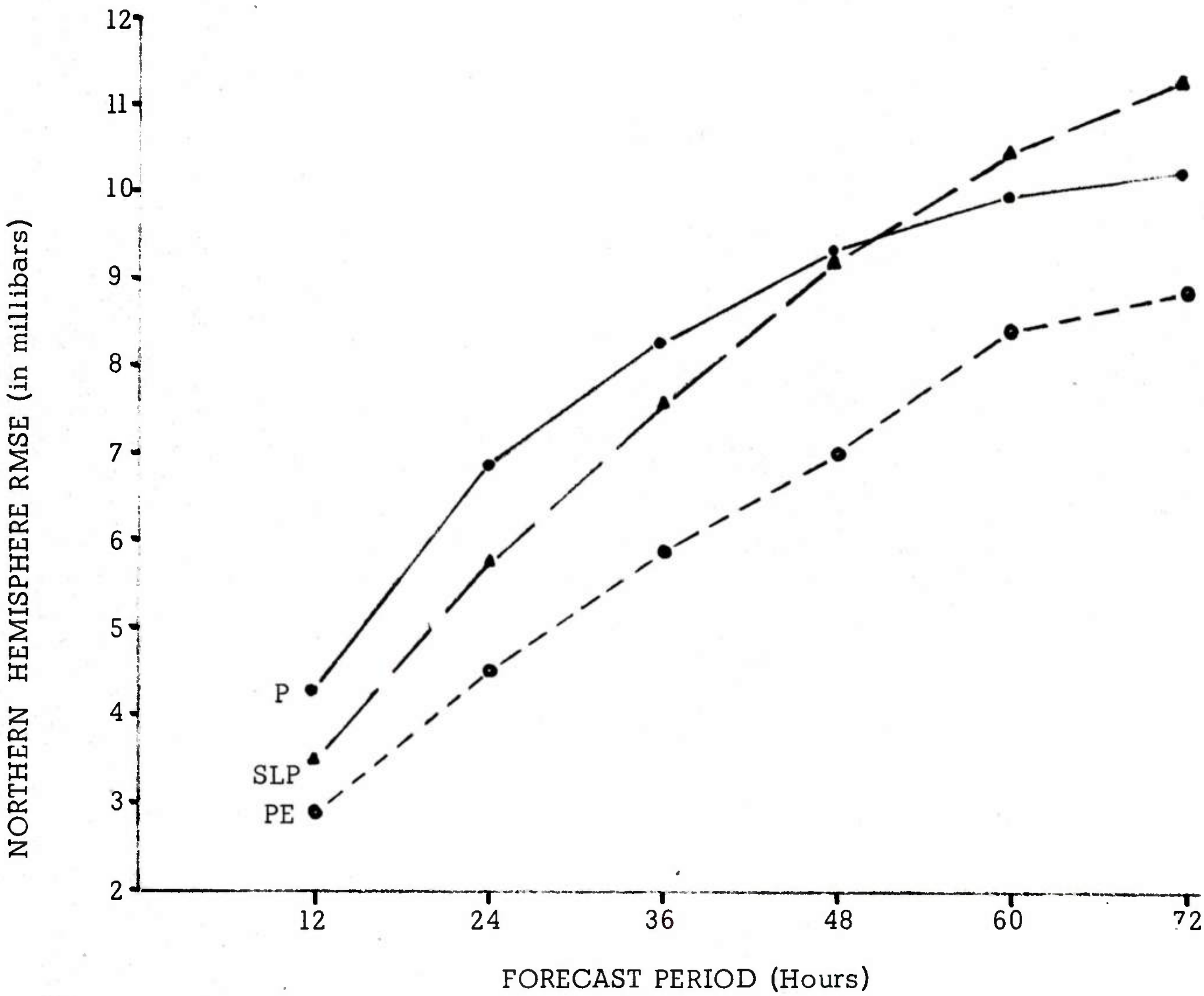

Figure 1. Summary of Verification Scores (RMSE) for all forecasts made in the month of November 1970 by the Primitive Equation Model (PE), the Sea Level Pressure Model (SLP), and Persistence (P). Every PE prog showed skill over persistence to 72 hours.

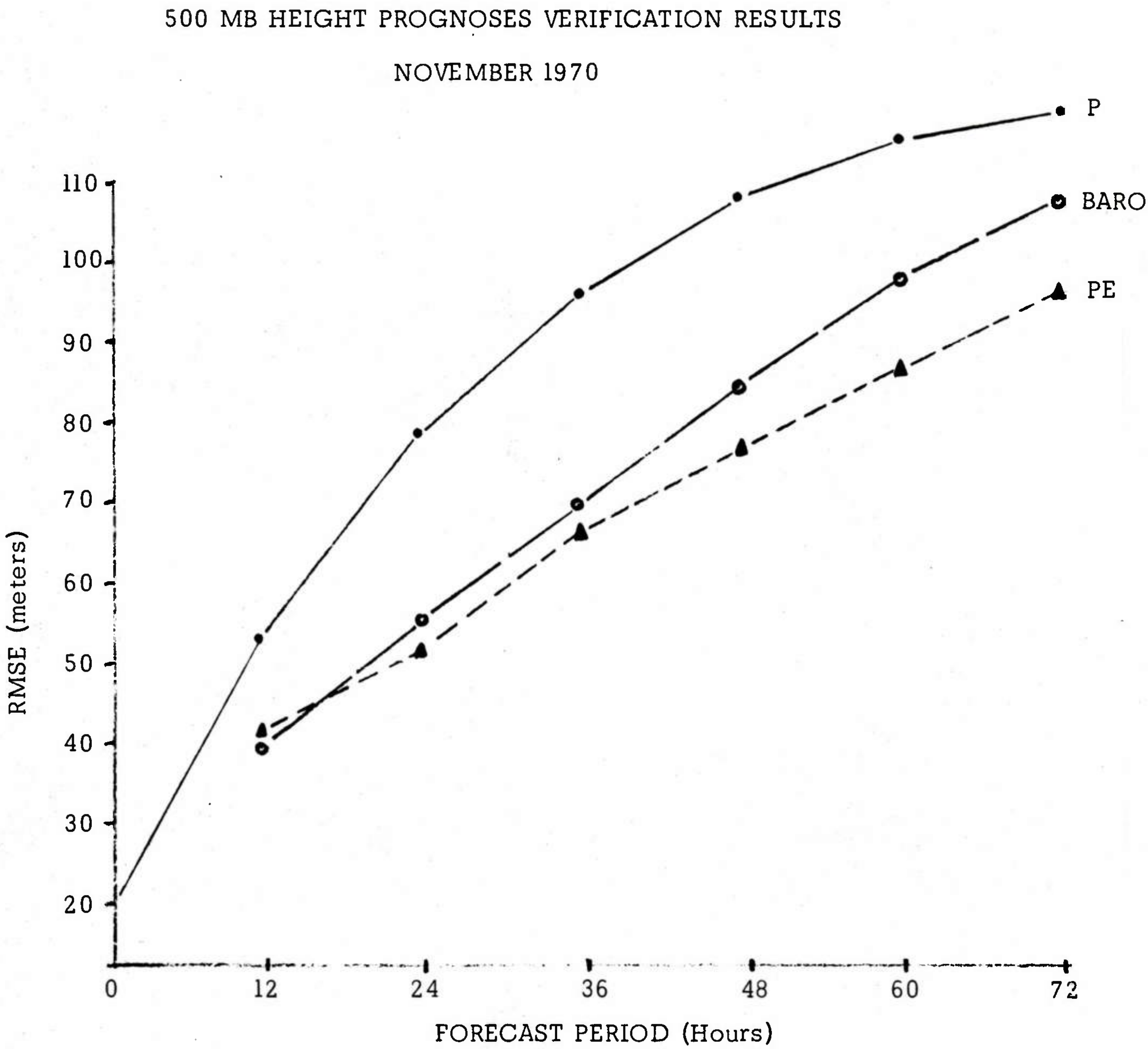

Figure 2. Summary of Verification Scores (RMSE) for all forecasts made in the month of November 1970 for the Primitive Equation Model (PE), the Barotropic Model (BARO), and Persistence (P).

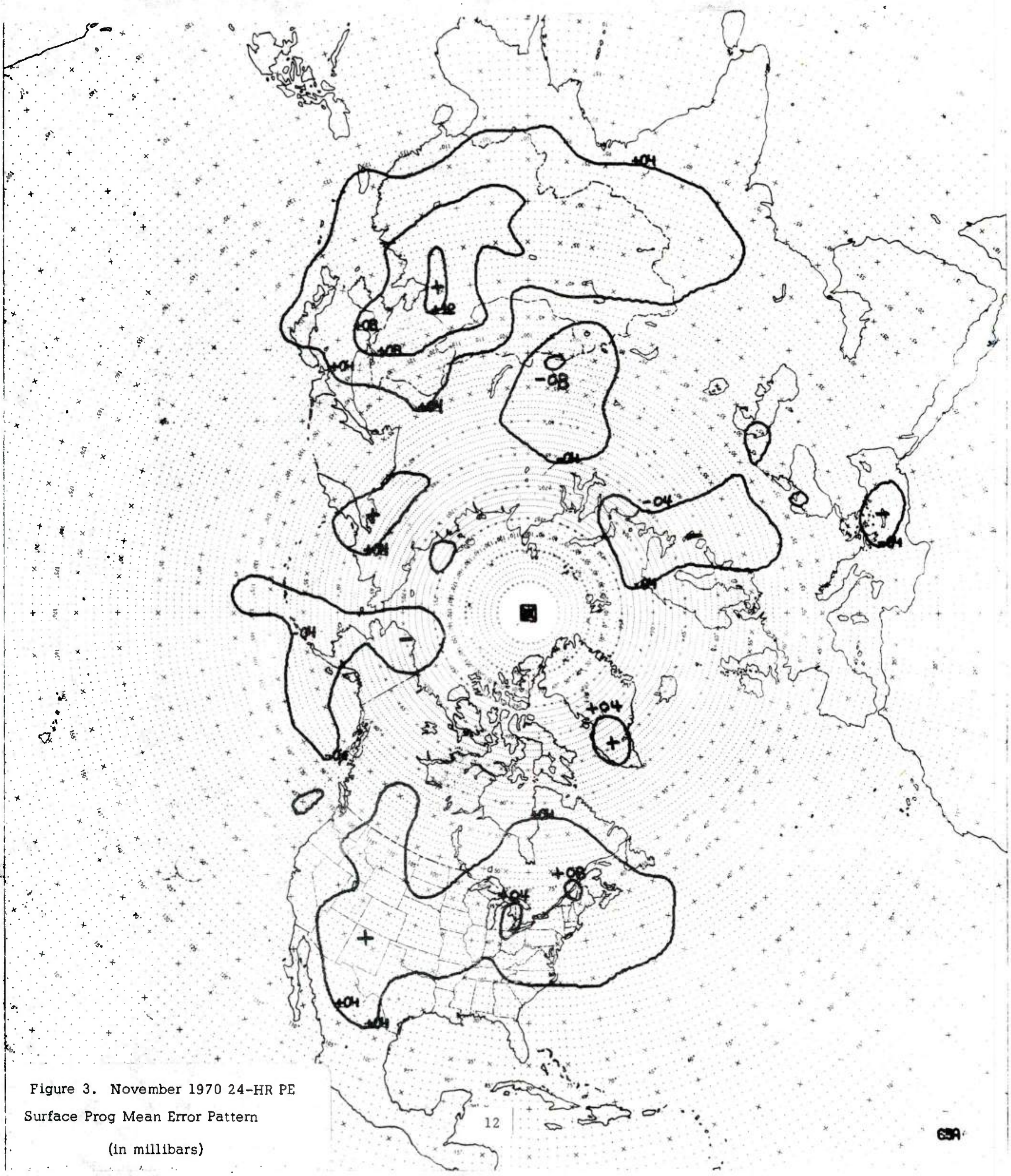

Figure 3. November 1970 24-HR PE Surface Prog Mean Error Pattern (in millibars)

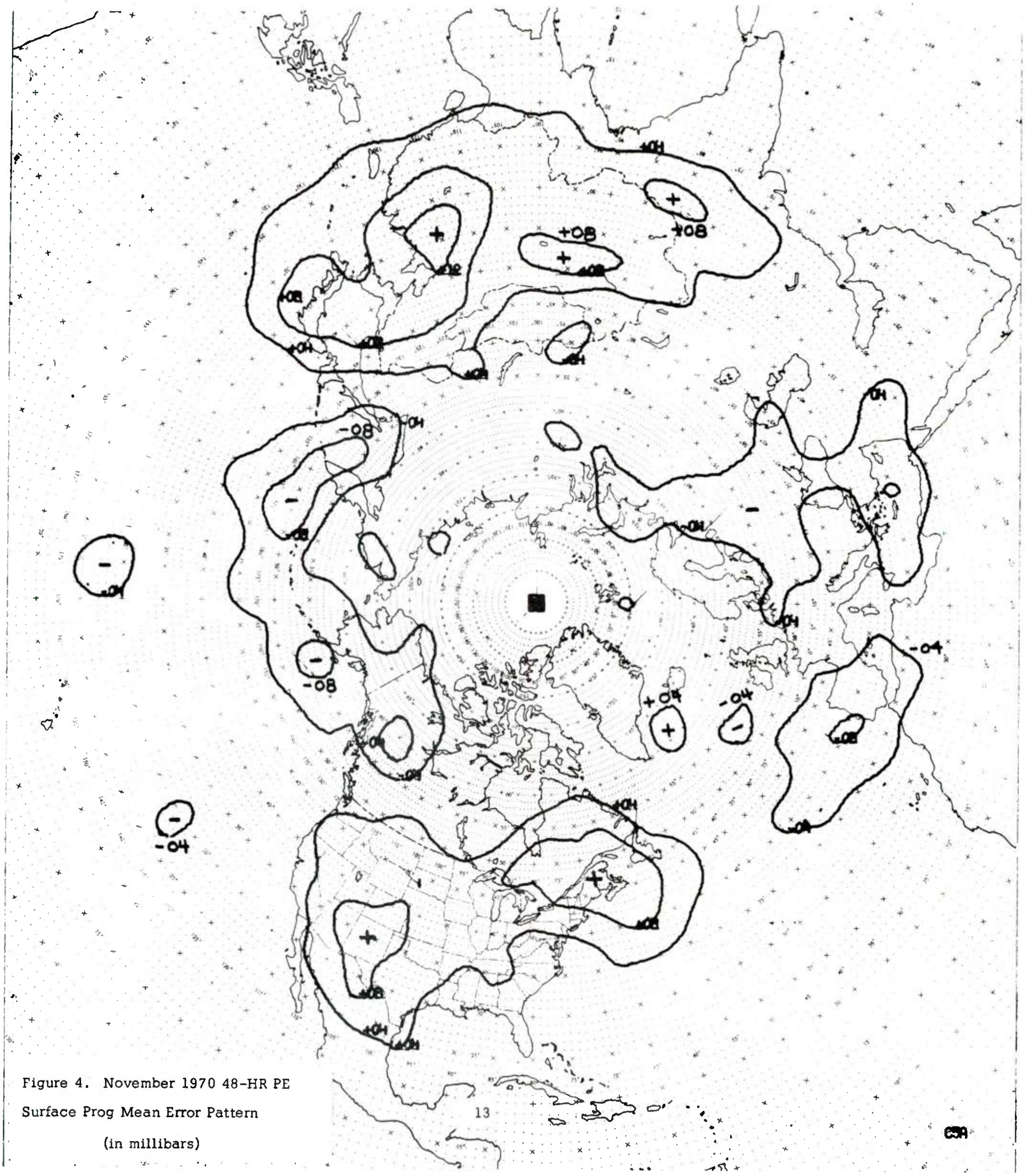

Figure 4. November 1970 48-HR PE Surface Prog Mean Error Pattern (in millibars)

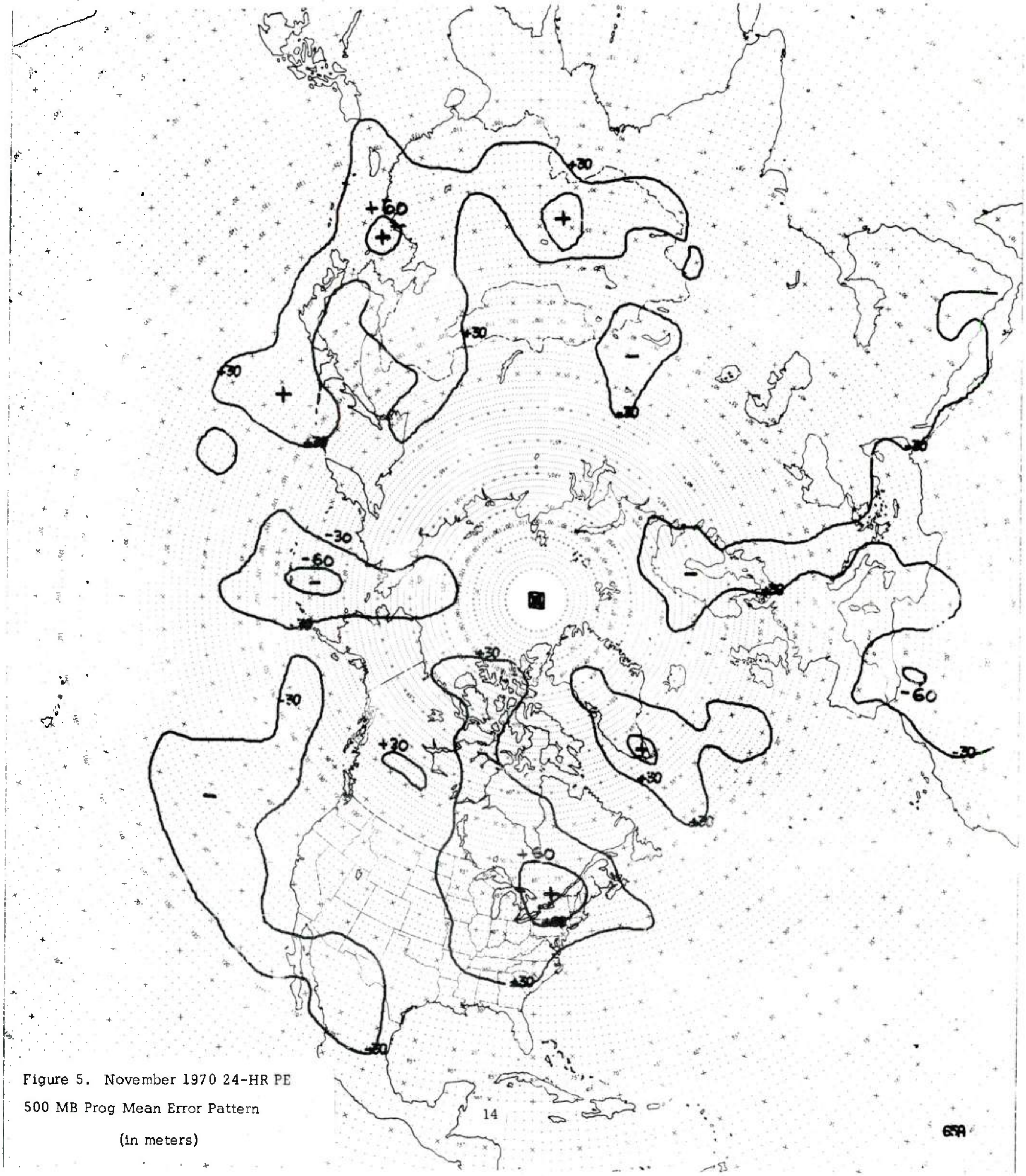

Figure 5. November 1970 24-HR PE
500 MB Prog Mean Error Pattern
(in meters)

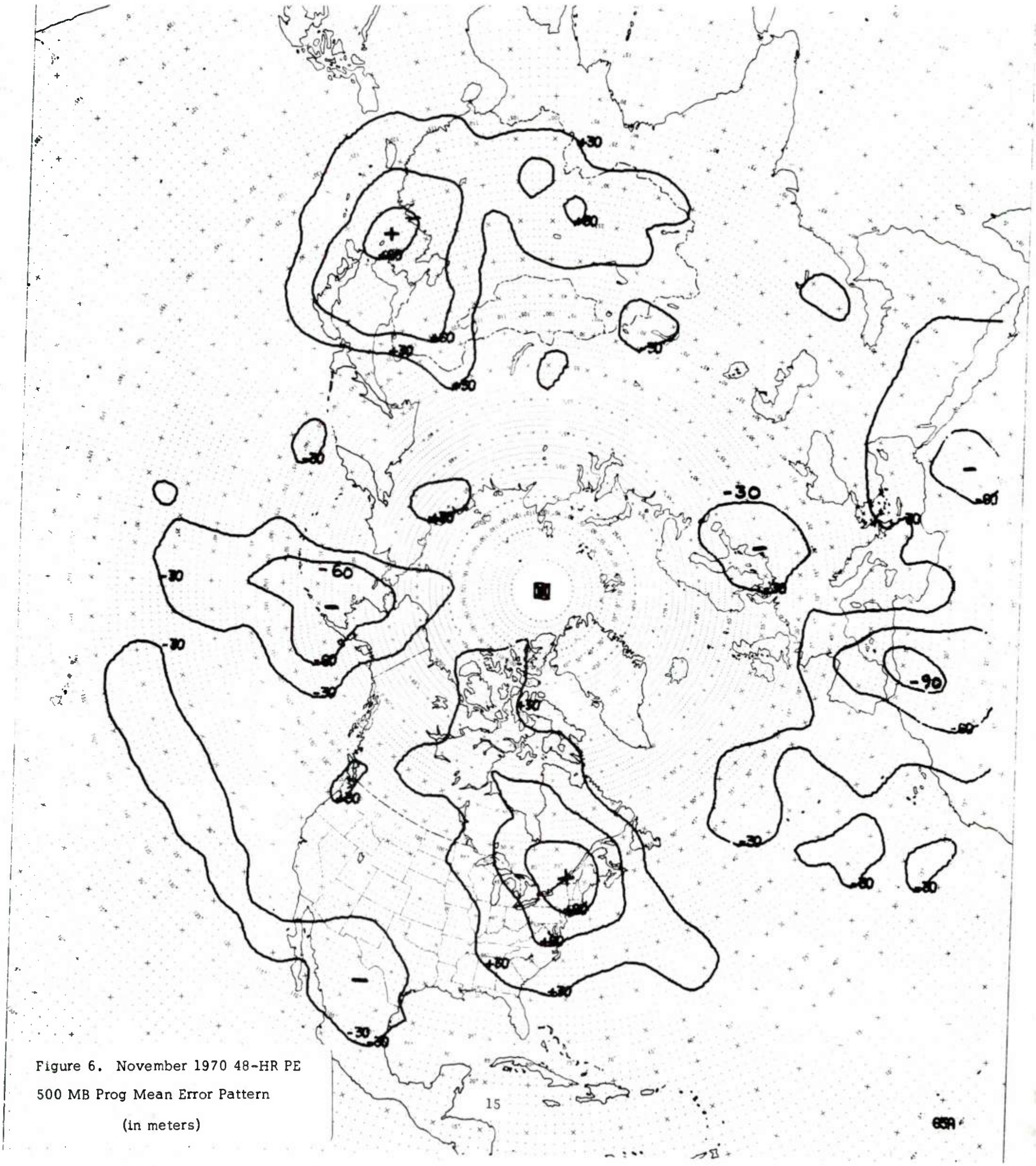

Figure 6. November 1970 48-HR PE 500 MB Prog Mean Error Pattern (in meters)